Spectrum sensing and energy detection in cognitive networks

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Article Info	ABSTRACT
	It is worth mentioning that the use of wireless systems has been increased in recent years and supposed to highly increase in the few coming years because of the increasing demands of wireless applications such as mobile phones, Internet of Things (IoT), wireless sensor networks (WSNs), mobile applications and tablets. The scarcity of spectrum needs to be into consideration when designing a wireless system specially to do the two following questions; how to utilize efficiently the spectrum available for the available networks in sharing process and how to increase the throughput delivered to the serving users. The spectrum sharing between several types of wireless networks where networks are called cognitive networks is used to let networks cooperate with each other by borrowing some spectrum bands between them especially when there is an extra band that is not used. In this project, the simulation of spectrum sensing and sharing in cognitive networks is performed between two cognitive networks. This project discusses the performance of probability of energy detected (Pd) with different values of false alarm (Pf) and Signal-To-Noise Ratio (SNR) values to evaluate the performance of the sensing and sharing process in cognitive networks. The results show that when the request of sharing spectrum increased, the full sharing process occurs for a long time and the error rate decreases for small values of SNR.

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1. INTRODUCTION

Sharing concept and heterogeneity process in wireless communication takes the consideration of most of reasearchers today to enhance the network capacity. Sharing between services or coverage area of radio access in 5G opens new challenges in optimizing users' access to the networks. The concept behind the sharing properties is that the mobile user does not connected only with its operator, but also has the ability to link with other operator near the previous one by using sharing resources [1]. The sharing concept appear on the surface of modern wireless communication researches becasue of the high demand of wireless applications and the increase of mobile units in the last decades which leads to increase in radio access usage [2]. The demand increases due to the increase in wireless applications, internet of things (IoT) and using online multimedia with high data rate which absolutly leads to think about systems that is robust to face the future challenges and demands of mobile services. Designing Radio Access Technology (RAT) is considered important in improving system capacity in a cost-effective manner.There are three types of resource sharing

in 5G networks such as spectrum sharing, access sharing and infrastructure sharing where Radio Resource Sharing (RRS) scheme between different mobile infrastructures occurs so as to provide mobile devices with the freedom to access all available radio resources around them [3]. Spectrum sensing is the process of periodically monitoring a specific frequency band, aiming to identify presence or absence of primary users, while spectrum sharing is simply the cooperative use of common spectrum by multiple users. Cognitive Radio (CR) networks is one of the resource sharing networks especially for spectrum sharing. These networks are available together in order to enhance the system performance and throughput by using the concept of sensing unused specteum and requesting to use this spectrum from one operator to another [4].

Summarizes the problem statement and limitation of the network resources constraints like spectrum sharing in modern wireless communication systems. The first problem is that there are many different networks infrastructure for many wireless networks in the same location. This leads to costly installation of infrastructure. The second issue is the available bandwidth in some networks that is not used while other systems suffer from heavy usage. The third issue is the heavy demand in one network while other networks in the same location are few which lead to the need of robust radio access or access sharing.

The motivation of this study comes from the scarcity of available spectrum with the increase in mobile units using another frequency bands such as millimeter-wave (mmWAVE) to achieve high data rate. MmWave networks include backhaul links, mmWave hotspots, and heterogeneous and homogeneous cellular networks. The use of mmWave or other unused frequency band has becomes more important because of different reason like using the unused frequency band that leads to efficient use of spectrum at different operators and wireless systems. The spectrum sharing between different operators leads to optimal use of the spectrum and infrastructure with the ultimate goal of maximizing benefits for citizens.

This paper is concentrated on three pf objective proposed method that starts from, investigate the background and practical aspects in cognitive networks. Second objective develop a simulation environment for spectrum sharing between two wireless operators while the last objective is to analyze the performance of spectrum sensing and sharing under probability of false alarm, probability of missed detection, and probability of energy detection as a performance metric of cognitive network.

The remainder of the article is as follows: Section 2 briefly describes the simple cognitive networks approach that is proposed for the proposed methadolagy. The proposed methadolagy is described in Section 3. In Section 4, results and discusion are presented in detail. Finally, Section 5 is the conclusion of this article.

2. RELATED WORKS

A. K. Bhattacharjee ,2017 [5] evaluates the two phase cooperative relaying scheme for spectrum sharing in a 2 x 2 overlay cognitive radio. They evaluate the performance considering secondary transmitter acts as decode and forward relay to the primary and employs hierarchical modulation to enhance primary SNR reception.[6].discuss resource sharing, a key dimension in mmWave network design in which spectrum, access and/or network infrastructure resources can be shared by multiple operators[3].presents a multi-carrier waveform based inter-operator spectrum sharing concept for 5G mobile and wireless communication systems to increase the capacity. While [7] simulate clustering towers to enhance spectrum available using Cloud Radio Access Network (C-RAN). Interference cancellation to enhance the capacity of the system is performed in [8] by using Dynamic Spectrum Sharing (DSS) and power control [9].

H. Gao,[10] enhances the capacity of the system by decreasing the time required for the spectrum sharing using cooperative mechanism (BCM) for wireless energy harvesting and spectrum sharing in 5G networks. [11] concentrates on spectrum flowing scheme for 5G cognitive heterogeneous cellular networks, which improves both spectral and energy efficiency.[12]improves network capacity and system computing capability using enhanced C-RAN (EC-RAN) to integrate local cloud services to provide a low-cost, scalable, self-organizing, and effective solution. While [13] discusses the radio resource management and sharing for uplink and downlink transmissions using NOMA to increase capacity.

O. Aydin, 2014 [14] simulates the MIMO network sharing among multiple operators considering three different service level agreements between the shared operators and the service provider, and gives an overview of the spectrum sharing concept and its emergence in 5G standardization [15, 16].

With the severe spectrum shortage in conventional cellular bands, millimeter wave (mmWave) frequencies between 10 and 300 GHz have been attracting growing attention as a possible candidate for next-generation micro- and picocellular wireless networks[17, 18]. The mmWave bands offer orders of magnitude greater spectrum than current cellular allocations and enable very high-dimensional antenna arrays for further gains via beamforming and spatial multiplexing [19, 20].

However, due to the unique nature of propagation in these bands, cellular systems will need to be significantly redesigned Resource sharing is among the most promising approaches to better leverage the

potential of mmWave-based frequencies in cellular communications. Resource sharing has common challenges with heterogeneous networks. Although densification has observable limits for microwave frequencies, it is shown that denser deployments are advantageous for mmWave bands because of their different propagation characteristics for non-line of sight NLoS and line of sight LoS environments[21, 22].

Network sharing has evolved from a novel concept a few years back with the arrival of the third generation (3G) networks to a fundamental feature of the emerging 5G systems. Mobile operators are facing tremendous traffic increases with the introduction of smartphones and tablets, especially due to content rich multimedia and cloud applications, and the upcoming vertical market services in automotive, e-health, and others [23]. The challenge for mobile operators is to accommodate such traffic volumes without significantly increasing operational and infrastructure costs [24]. The trend toward network densification for increasing network capacity and the practice of overprovisioning to accommodate peak demands including future traffic volumes adds additional burdens to operational complexity and cost, diminishing the Return on Investment (RoI) [25, 26].

3. METHODOLOGY

There are three performance metrics used in this project, the first one is the probability of false alarm (pf), the second one is the probability of energy detected (Pd) and the last one is the probability of missed detection (Pm). The description of these parameters is as follows:

3.1. Probability of false alarm (Pf)

It is the probability of falsely detecting the primary signal when the primary user is actually silent in the scanned frequency band and calculated as in equation 1.

$$Pf = EX|\theta \, [\varphi(X) \mid \theta] = \int x1 \, p(x \mid \theta) \, dx \text{ for } \theta \text{ in} \Theta_0 \tag{1}$$

Where:
$EX|\theta$ = the probability of X with respect to θ
$\varphi(X)$ = the value of the user function
$x1$ = user number 1
$\Theta 0$ = area of the decision is the first one

3.2. Probability of missed detection (Pm)

It is the probability of failing to detect energy from the secondery network when the primary user is actually request a spectrum sharing (sensing the spectrum) and calculated as in equation 2.

$$Pm = EX|\theta \, [1- \varphi(X) \mid \theta] = 1- \int x1 \, p(x \mid \theta) \, dx = \int x0 p(x \mid \theta) \, dx \text{ for } \theta \text{ in} \Theta 1 \tag{2}$$

Where:
$\Theta 1$ = area of the decision is the second

3.3. Probability of energy detected (Pd)

It is the probability of detecting a suitable energy from the secondery network when the primary user is actually request a spectrum sharing (sensing the spectrum) and calculated as in equation 3.

$$PD=1- PM = EX|\theta \, [\varphi(X) \mid \theta] = \int x1 \, p(x \mid \theta) \, dx \text{ for } \theta \text{ in} \Theta 1 \tag{3}$$

Table 1 sammurized the parameters used in this comparitive study. There are two operators in the scenario as mentioned above named by PN and SN to perform together a cognetive network. Number of users used in this project is 5 and 10 to simulate the effect of changing number of users in the network. The modulation used is BPSK and changed to QPSK to also make a comparison between the effect of using the two types on the performance metrics under study [20]. The channel type is AWGN.

Table 1. The Performance of

Parameters	Value
Number of operators	2
Base station density	5, 10
Modulation type	BPSK, QPSK
Transmitting power	30 dBm
Channel type	AWGN
SNR (dB) as a x-axis	[-16, 0]

4. RESULTS AND DISSCUATION

The simulation results about the performance evaluation of the cognitive network scenario mentioned in Figure 1. It consists of three subsections that are deal with all performance metric mentiond in section 3 The first section simulate the perfoemance of Pd with respect to different values of pf and compare the results with that obtained theoritically. The second sebsection simulate the effect of changing the value of SNR on the Pd values, and performs simulation to study the effect of changing number of users on the network on the missed probability Pm with respect to Pf. The path loss exponent effect on Pm is also simulated here in this section for different values of path loss. The last section in simulation is performed to study the effect of changing number of sharing requests from 1 to 10 on the error rate of the system with respect to different values of SNR. This section simulates the spectrum sensing and sharing between two cognitive networks by means of probability of false alarm (pf) and probability of energy detection (Pd). Pf denotes the probability of a cognitive radio (CR) network user declaring that a primary user (PU) is present when the spectrum is actually free. Pd is the probability of a CR user declaring that a PU is present when the spectrum is indeed occupied by the PU as mesntioned in section 3.

Cognitive user needs to accurately detect whether the current band is occupied by a licensed user to ensure the licensed user's use of specific bands. Spectrum sensing and sharing algorithms in CR can be mainly divided into three types: energy detection, match filter detection, and cyclostationary detection. Among them, energy detection has been widely applied since its algorithm is simple, and it does not require transcendental knowledge of the licensed user's signals.Due to the interference factors, such as multipath and shadow effect of wireless channels, energy sensing conducted by single cognitive sensing node that has low SNR of the received signal.

Figure 2 shows the results of Pd vs. Pf at SNR = -10 dB and AWGN channel. The simulation result shows an acceptable performance between theoritical result when applying equation 3.1 and the results obtained from the simulation under the same value of SNR. It is clearly seen that there is a greate chance of false detection at higher Pd. This is because of the increasing number of sharing spectrum when Pd increased where the probability of the new sharing applying is decreased (false alarm increased).
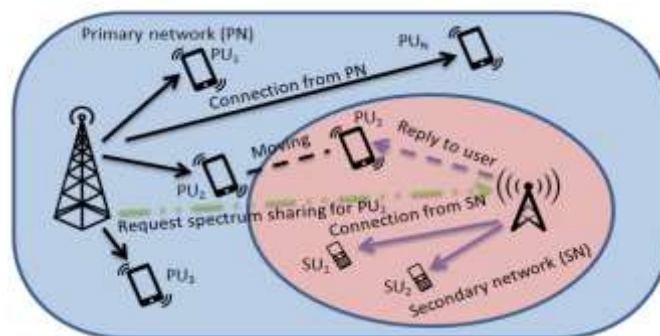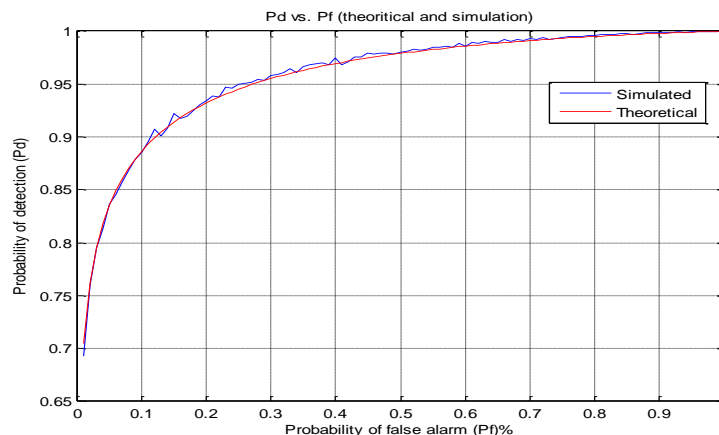

Figure 1. Simulation scenario

Figure 2. Probability of shared spectrum detection vs. probability of false alarm response

Figure 3 shows the probability of energy detection Pd that gives the probability of false alarm Pf = 1%, 5% and 10% versus the different values of SNR at AWGN and BPSK modulation. For the three curves mentioned, the Pd is almost 100% for SNR=-7 dB or higher. All curves start to decrease with the decrease in the SNR with noticeable outperforming of the Pf=5% and 10% curves. At SNR = -16 dB, Pd = 16% for Pf = 10%, Pd = 6% for Pf = 5% and finally Pd = 2% for Pf = 1%. This concept behind the values clearly accepted with that obtained in Figure 4 which states that there is a great chance of false detection at higher Pd
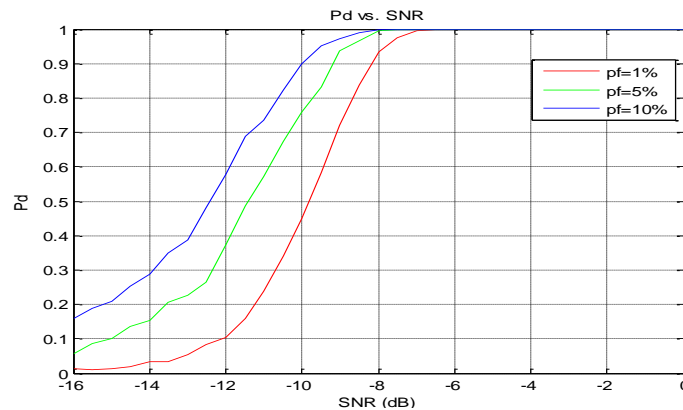

Figure 3. Probability of energy detection vs. SNR at different values of Pf

Figure 4 shows the responce of Pd with respect to different values of SNR at Pf equals 5% and BPSK and QPSK is used as a modulation. The results show that there is a slightly acceptance between the two curves which means that the modulation types do not affect the Pd values at the same value of Pf. The relation is only depends on the SNR of the signal.
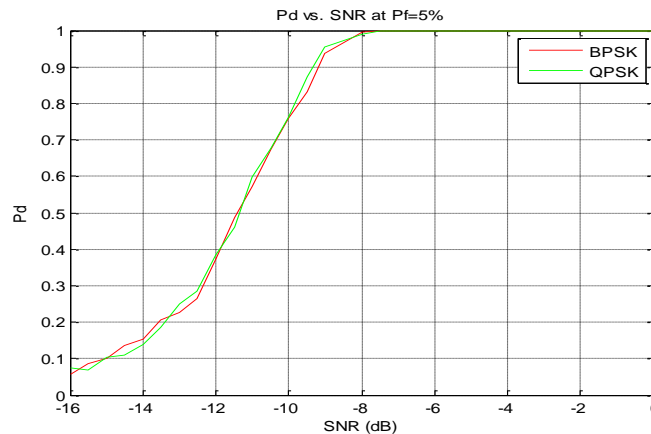

Figure 4. Probability of energy detection vs. SNR at Pf=5% for BPSK and QPSK

Figure 5 shows the inverse responce of Figure 2, where probability of missed spectrum sensing and sharing (Pm) is inversily proportional to the probability of false alarm at path loss exponant equals 2 and SNR= -5 dB. Pm starts at 100% when no false alarm of sensing occured. From figure 5, the missed detection is still 100% regardless the number of users in the system untill to reach 40%. When number of users equals 5, the Pm percentage is decreased which means that the Pd value increased and the spectrum sharing starts to ocuure until to reach 100%. When number of users increase to 10, the Pm value is still high and equals 100% untill the Pf reaches 60%. This is because of the interference increase between users and increasing in demand of spectrum sharing between the cognitive networks. These results are also accepted with that obtained from Figure 2.
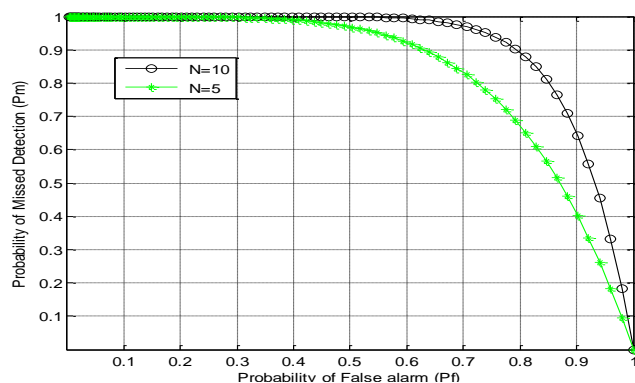
Figure 5. Pm vs. Pf at path loss exponent =2 and SNR=-5 dB for different values of users

Figure 6 shows the results of Pm versus Pf when changing the value of SNR as -5 dB, 10 dB and 25 dB in order to study the effect of changing SNR on the Pm values. The simulation performed at path loss exponent equals 2 and number of users equals 5. The simulation results show that the there is an match on the performance of Pm at SNR = -5dB and 10dB. This is because of the need of high SNR values in order to decrease Pm to enhance Pd. This is appears when SNR reaches 25 dB where the results of Pm deacrese more fast than other values of SNR.

Figure 7 shows the results of Pm versus Pf when changing the value of path loss exponent in order to study the effect of changing path loss on the Pm values. The simulation performed at SNR values equals to 10 dB and number of users equals 5. The simulation results show that the there is no effect on the path loss exponent on the Pm with respect to Pf. This is because the Pd is dependent on the value of the signal strength and the need of spectrum which means ot depends on the distance between users and base station not the sorrounding area of the operators.
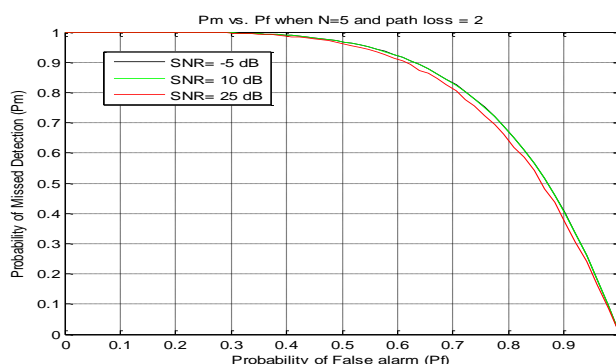

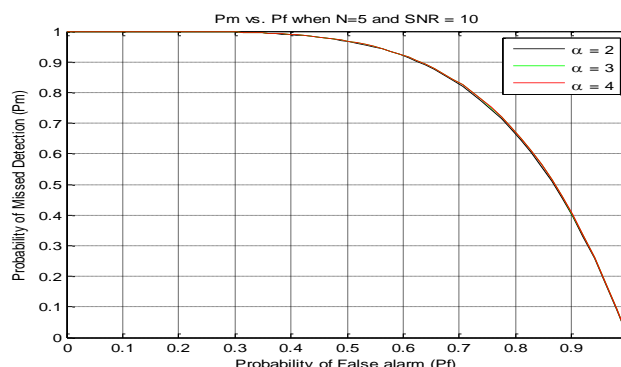Figure 6. Pm vs. Pf at path loss exponent =2 and N=5 for different values of SNR

Figure 7. Pm vs. Pf at N=5 and SNR = 10 dB for different values path loss exponent

To complete the study of how spectrum sharing occures in cognitive networks, there is an important to show the effect of multiple sharing request from the primery user in different network to the cognitive network. Figure 8 shows the error rate performance which is equal to the summation of Pf and Pm with respect to different number of values and different number of requests which indicates as n in the figure. Number of requests is the number that useres sends request to the network to perform connection to the new network which means to use another spectrum.Figure 8 shows that when the number of spectrum sharing requests increase the error performance decresed. The figure shows that when n equals 10, the error rate reaches 10^{-1} at the SNR equals 15 dB, while when n equals 5, the error rate reaches the same value at 24dB SNR.
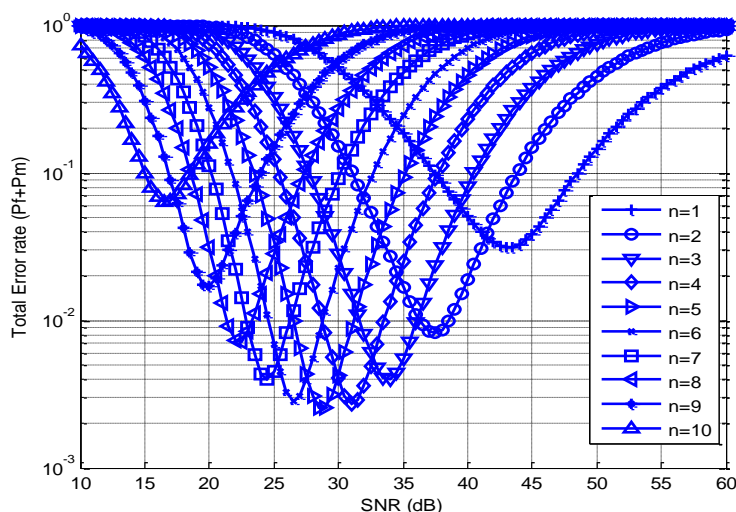

Figure 8. Error rate performance of changing number of sharing requests

5.   CONCLUSION

This paper discusses the performance of propability of energy detection with different values of false alarm and SNR values to evaluate the performance of the cognitive network system. It is clearly from results that there is a greate chance of false detection at higher Pd. This is because of the increasing number of sharing spectrum when Pd increased where the probability of the new sharing applying is decreased (false alarm increased). the simulation of the the path loss exponent effect shows that there is no effect of changing the path loss because the cognitive operation depends on distance between operators and available spectrum to hare not on the sourrounding area.

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